Nepal Journal of Multidisciplinary Research (NJMR)
Vol. 8, No. 2, Special 1, 2025. Pages: 161-185
ISSN: 2645-8470 (Print), ISSN: 2705-4691 (Online)
DOI: https://doi.org/10.3126/njmr.v8i2.78026

Digital Transformation of Education: A Bibliometric Analysis of Artificial Intelligence in Learning

Janga Bahadur Hamal
Faculty of Management
Tribhuvan University, Kathmandu, Nepal
janga.hamal@smc.tu.edu.np

Ramesh Prasad Sapkota*
Central Department of Environmental Science
Tribhuvan University, Kathmandu, Nepal
rsapkota@cdes.edu.np

Laxman Kandel
Faculty of Management
Tribhuvan University, Kathmandu, Nepal
laxmankandel61@gmail.com

Sukra Raj Adhikari
Lincoln University College, Malaysia
adhikari.sukra@gmail.com

Corresponding Author*
Received: March 01, 2025 Revised & Accepted: April 21, 2025

Abstract

Background: Artificial intelligence (AI) has significantly enhanced growth and productivity across various socioeconomic sectors, including education. By facilitating personalized, data-driven, and adaptive learning experiences, AI is reshaping educational pedagogies. The purpose of this study is to methodically examine the role of AI in education and to contribute to the existing literature concerning the future of learning.

Methods: To achieve the objective, a bibliometric analysis was conducted using the Dimensions database, covering research on AI in education and future of learning from 2016 to February 2025. VOSviewer was employed for bibliometric mapping, including citation

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analysis, co-citation networks, bibliographic coupling, and co-authorship analysis, to identify key research trends, themes and influential contributors.

Results: The findings indicate a notable increase in AI-related educational research, particularly from 2021 onwards, highlighting a growing academic interest in the field. Geographical analysis indicates that the United States and China are the most prolific in AI-related educational research, indicating the need of advancing the use of AI, especially in the developing countries. Addressing the differences in the use of AI across countries necessitates the strategic efforts to bridge technological gaps and promote inclusive of AI in education systems. The findings also underscore the importance of addressing ethical considerations, data privacy, and algorithmic biases to ensure equitable access to AI technologies. Furthermore, the examination of top academic journals reveals varying levels of influence, with some achieving high impact through select, highly cited publications.

Conclusion: The study emphasizes the transformative impact of AI on education, revealing a clear shift toward more personalized, adaptive, and data-driven learning environments. It also provides valuable insights into the evolving landscape of AI in education, emphasizing its interdisciplinary nature and transformative potential.

Novelty: By highlighting research trends, themes and key contributors, this study serves as a foundational resource for scholars seeking to navigate and advance the field. The study contributes to the broader discourse on AI in education, offering guidance for future research directions.

Keywords: artificial intelligence, bibliometric analysis, education, learning, VOSviewer

Introduction

Artificial Intelligence (AI) is revolutionizing various industries worldwide, and the education sector is no exception. The integration of AI-driven technologies into learning environments has brought significant changes, shifting traditional pedagogical approaches toward more personalized, data-driven, and adaptive learning experiences (Liu et al., 2018). AI-powered innovations, such as intelligent tutoring systems, adaptive learning platforms, and predictive analytics, have fundamentally transformed the ways students acquire knowledge, engage with content, and receive feedback (Luckin et al., 2016). This shift towards AI-assisted education is redefining the role of educators and students alike, fostering a more interactive and customized approach to knowledge dissemination.

One of the most profound implications of AI in education is its ability to tailor learning experiences to individual students' needs. AI-driven adaptive learning systems analyze students' learning patterns, strengths, and weaknesses to create personalized lessons and assessments (Kelley et al., 2020). This method enhances learning efficiency by allowing students to progress at their own pace while receiving targeted support. Additionally, AI-powered intelligent tutoring systems provide real-time assistance by simulating human tutors through natural language processing and machine learning algorithms. These systems offer instant feedback, answer queries, and facilitate a deeper understanding of complex subjects, thereby bridging learning gaps and supplementing traditional classroom instruction.

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Beyond personalized learning, AI plays a pivotal role in educational data analytics and decision-making. By leveraging vast datasets, AI enables institutions to identify trends, predict student performance, and implement timely interventions (Luan et al., 2020). AI-driven insights help educators optimize curricula, enhance student engagement, and address learning challenges proactively. Furthermore, AI facilitates automated assessment and feedback mechanisms, streamlining grading processes and allowing educators to focus on pedagogical improvements (Siemens & Long, 2011). AI in education has been extensively studied, with scholars exploring its implications for pedagogy, learning methodologies, and institutional decision-making. AI-driven personalized learning systems have been recognized for their ability to cater to individual student needs, providing customized learning pathways (Luckin, 2018). Research highlights the effectiveness of adaptive learning models in fostering self-regulated learning and student autonomy (Baker & Yacef, 2009). Furthermore, studies on AI-based intelligent tutoring systems underscore their capability to provide real-time feedback and enhance conceptual understanding (VanLehn, 2011).

The role of AI in educational data mining and learning analytics is another key research area. AI technologies have enabled institutions to predict student performance and intervene proactively, thereby improving academic outcomes (Siemens & Long, 2011). Moreover, AI has facilitated automated assessment and grading systems, significantly reducing the administrative burden on educators (Chen et al., 2020). However, the widespread adoption of AI in education raises ethical and accessibility concerns. Issues such as data privacy, algorithmic bias, and the digital divide require careful consideration (Selwyn, 2019). Research has emphasized the need for robust policy frameworks to ensure equitable AI implementation in educational settings (Zawacki-Richter et al., 2019).

The global disparities in AI adoption present another critical research challenge. While developed countries have rapidly integrated AI into education, many developing nations struggle with infrastructure limitations and resource constraints (Chatterjee & Bhattacharjee, 2020). This digital divide necessitates further investigation into strategies for bridging technological gaps and promoting inclusive AI adoption worldwide. The growing adoption of AI in education underscores its potential to revolutionize learning experiences, but it also raises important considerations regarding accessibility, ethics, and the digital divide. While AI-driven tools offer unprecedented opportunities for educational advancement, challenges such as data privacy, bias in algorithms, and equitable access to AI technologies must be addressed to ensure inclusive and effective implementation.

This study aims to conduct a bibliometric analysis on assessing the research publication trends, most cited studies, research themes, and key contributors in AI in learning. By examining the existing body of knowledge, this paper seeks to provide valuable insights into the evolving role of AI in shaping educational methodologies, highlighting both the opportunities and challenges associated with its integration. The findings will contribute to the broader discourse on AI in education and inform future research directions in this rapidly expanding field.

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Research Methods

Source of Data

Understanding the nature and dynamics of AI in education and future of learning is the primary objective of this research. To facilitate an efficient evaluation, it is essential to employ a well-defined set of search keys. Choong (2013) proposed a technique for selecting keywords that effectively address the underlying concepts of data, ensuring that the search process captures the most relevant literature. A systematic approach was used for the literature search, incorporating electronic database searches along with backward and forward reference searches to ensure the inclusion of all pertinent studies (Eduardsen & Marinova, 2020). The study relies on the Dimensions bibliometric database, a widely recognized academic resource provided by Digital Science, known for its extensive coverage and robust impact metrics (Thelwall, 2018). The use of this database ensures comprehensive identification of AI in education research and future of learning by utilizing advanced search queries and keyword-based filtering in VOSviewer, thus providing a structured framework for meaningful bibliometric analysis.

The dataset for this study was exported on February 17, 2025, and includes peer-reviewed academic articles published from 2016 to February 2025 for a period of about 10 years. The selection criteria focused on journal articles, proceedings and preprints from reputable open-access journals. The inclusion of these journals aligns with major academic indices, including the Directory of Open Access Journals (DOAJ), VABB-SHW, Excellence in Research for Australia (ERA 2023), the European Reference Index for the Humanities and Social Sciences (ERIH PLUS), Norwegian Register Level 1, UGC Journal List Group II, and Non-APC Journals. This selection process ensures that the dataset represents a broad and high-quality collection of studies on AI in education and future of learning. The search process was designed to maximize relevance while minimizing extraneous results. To maintain dataset precision, this study employed the following Boolean search query: ("artificial intelligence in education" OR "AI in education" OR "AI in learning" OR "digital transformation of education" OR "machine learning in education") AND ("impact on student learning" OR "AI and learning outcomes" OR "future of AI in education") AND ("secondary education" OR "high school students" OR "higher education" OR "university students") NOT ("business applications" OR "financial education" OR "AI in finance" OR "AI in healthcare" OR "corporate training"). The search was limited to the "topic" field, covering titles, abstracts, and keywords, ensuring that the collected articles directly addressed AI's role in education. Only scientific articles written in English were included, while book reviews, editorials, and non-peer-reviewed materials were excluded to maintain the dataset's academic rigor. The bibliometric analysis encompasses multiple analytical techniques, including research publication trends, citation-based metrics and co-authorship network analysis. These methods help identify key research trends, themes, and influential contributors within the field. To ensure data accuracy, preprocessing steps were implemented, including the removal of duplicate records and normalization of author names.

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Data Analysis Tool

VOSviewer, developed by Van Eck and Waltman (2010), was utilized for analysis and the creation of visual maps through its VOS clustering and mapping methods. These methods assess relationships and frameworks within datasets. Van Eck and Waltman (2007) introduced a precise technique for normalizing co-occurrence frequencies, which VOSviewer integrates to enhance the accuracy and meaningfulness of its maps and visual representations. The integration of this technique improves data insights, making visualizations more reflective of inherent relationships and patterns. Appio et al. (2016) highlighted the LinLog/modularity normalization method used in the study. Through VOSviewer, the researcher identified intricate patterns based on mathematical relationships within the dataset. This comprehensive process encompassed citation analysis, co-citation analysis, research trends, themes, and influential contributors.

Citation analysis reveals key research themes, emerging trends, and methodologies, helping trace a discipline's historical focus, as Allahverdiyev and Yucesoy (2017) emphasized. Document co-citation analysis, discussed by scholars including Appio et al. (2016), Fahimnia et al. (2015), and Verma et al. (2023), utilizes network theory (Liu et al., 2015) to identify data structure and relationships, creating informative maps. Excel has also been employed as an analysis tool for the tabulation and graphical presentation along with VOSviewer in the study. Bibliometric mapping illustrates relationships among authors and publications, providing insights into AI-driven educational research progression. The word cloud has been generated using wordshift.org as employed earlier by Neupane and Lourdusamy (2024). This bibliometric approach identifies key research themes and trends in AI's impact on education, contributing valuable insights to scholarly discourse on AI's role in transforming learning environments.

Results and Findings

Publications and Citation Trends

Publication and citation trends are essential metrics in bibliometrics, providing insights into the growth and impact of scientific literature over time. These trends help researchers understand the evolution of research topics, the emergence of new fields, and the influence of specific works or authors (Bornmann & Mutz, 2015; Larivière et al., 2016). Analyzing publication and citation trends can reveal patterns in research productivity, collaboration, and the dissemination of knowledge across disciplines (Larivière et al., 2016).

Table 1 illustrates the publication trends on Artificial Intelligence (AI) in Education from 2016 to 2025, demonstrating a substantial increase in research output over this period. The data indicate a relatively modest number of publications between 2016 and 2020, with annual counts ranging from 5 to 20, suggesting that AI in education was in its early stages as a research domain during this time. However, beginning in 2021, a notable upward trajectory emerges, with the number of publications rising from 28 in 2021 to 91 in 2023.

A particularly sharp increase is evident in 2024, with 250 publications—the highest recorded figure within the dataset. This exponential growth suggests a peak in scholarly interest, potentially driven by advancements in AI-powered learning systems, adaptive education

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technologies, and policy initiatives supporting AI integration in educational contexts. While the publication count for up to February of 2025 (49 publications) appears lower, this discrepancy may be attributed to incomplete data collection for the year.

Overall, the observed trend highlights the growing academic focus on AI in education, reflecting a shift from theoretical inquiry to applied research. The significant surge in recent years underscores AI's expanding role in personalized learning, automated assessment, and intelligent tutoring systems, signaling continued innovation and scholarly engagement in the field.

Table 1. Trend of publications

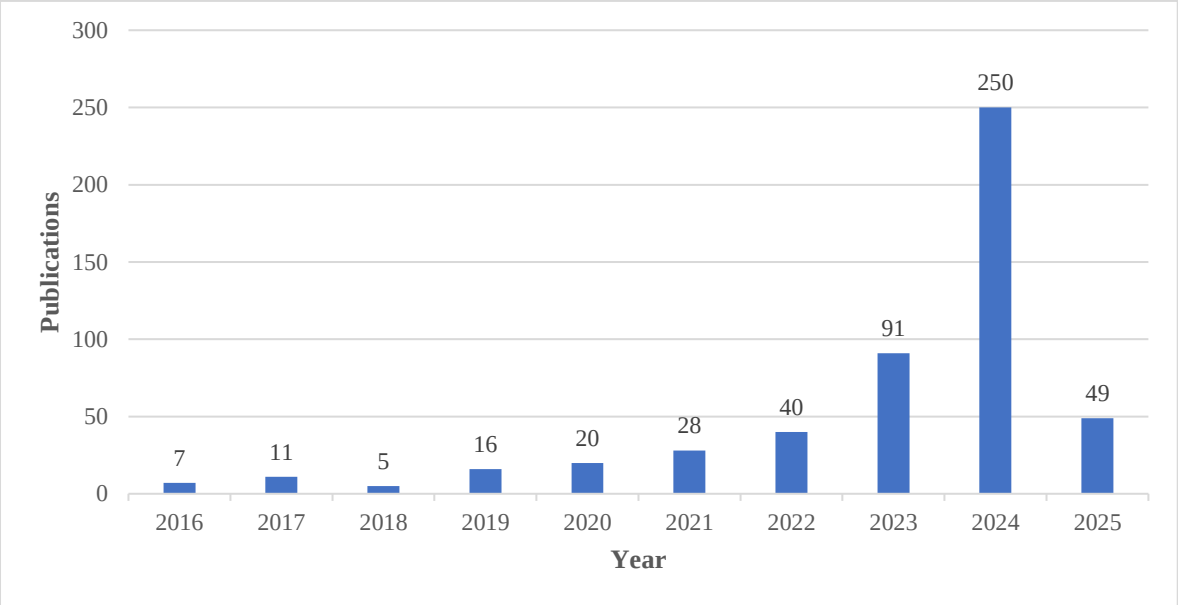

Figure 1 presents an analysis of citation trends from 2016 to 2025, revealing notable fluctuations in the number of citations per year. In the initial years, citation activity remained moderate, with 600 citations recorded in 2016 and 518 in 2017. However, a sharp decline followed in 2018, with only 84 citations, before a substantial increase in 2019, reaching 1,267 citations.

The upward trend continued, albeit with some variability, as citations rose to 666 in 2020 and 801 in 2021. The most pronounced surge occurred in 2022 and 2023, with citation counts peaking at 1,556 and 2,489, respectively. This peak was followed by a decline in 2024, with 1,077 citations, and a 4 citations in 2025 till the date of data extraction.

These fluctuations suggest alternating periods of heightened research activity and scholarly interest, interspersed with phases of lower citation counts. The substantial increase in recent years may reflect the growing academic focus on AI in education, whereas the decline in 2025 could be attributed to delays in citation accumulation or shifts in research priorities.

Figure 1. Number of citations per year

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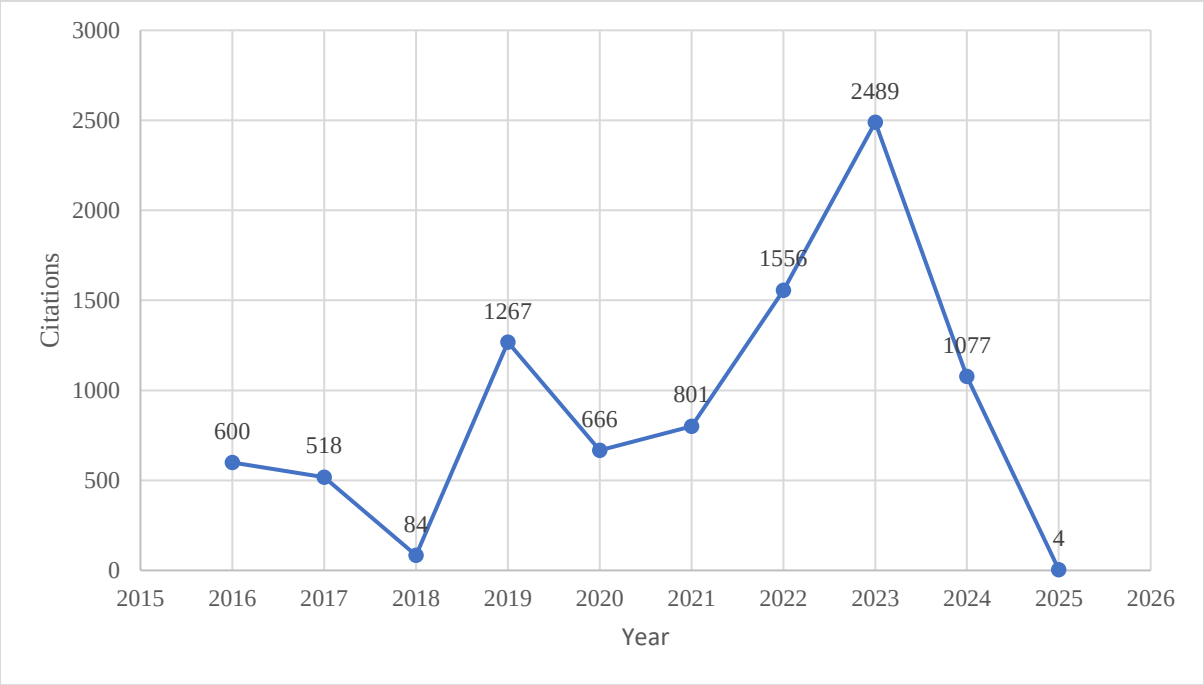

Top Cited Articles

The analysis of the most cited articles in the field of AI in education, as presented in Table 2, reveals several key trends and insights. The highest-ranked article, *State of the Art and Practice in AI in Education* by Holmes et al. (2022), published in the *European Journal of Education*, has accumulated 282 citations, reflecting its substantial influence on the academic community. Similarly, the second-ranked article by Chattaraman et al. (2019), published in *Computers in Human Behavior*, also with 282 citations, underscores the growing scholarly interest in the practical applications and interaction styles of AI in educational settings.

The third most cited work, *Unlocking the Power of ChatGPT: A Framework for Applying Generative AI in Education* by Su et al. (2023), with 264 citations, highlights the increasing research focus on generative AI technologies, particularly ChatGPT. This trend is further supported by the fourth-ranked article by Bahroun et al. (2023) in *Sustainability*, which has received 257 citations and provides a comprehensive review of generative AI applications in education. Foundational studies continue to exert a significant impact on the field. For instance, *Stupid Tutoring Systems, Intelligent Humans* by Baker et al. (2016) and Belland et al.'s (2016) synthesis of empirical research on computer-based scaffolding in STEM education remain highly influential, with 253 and 225 citations, respectively. These works have laid the theoretical and empirical groundwork for subsequent AI-driven educational technologies.

More recent contributions reflect the ongoing advancements and applied implementations of AI in educational contexts. For example, Chen et al. (2022) explore the role of AI-powered student assistants, while Chiu et al. (2023) examine teacher support and student motivation in AI chatbot-integrated learning environments. Additionally, Luckin's (2018) learning sciences-driven approach to designing AI-based educational technologies highlights the interdisciplinary nature of current research in this domain.

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The citation analysis suggests a balanced distribution of theoretical frameworks, empirical investigations, and practical applications, illustrating the dynamic and evolving landscape of AI in education research. The growing emphasis on generative AI, adaptive learning technologies, and AI-driven student support systems indicates a shift toward applied innovations with direct implications for teaching and learning practices.

Table 2. Most cited articles

Rank	Title	Journal	Year	Citations	Authors
1	State of the art and practice in AI in education	European Journal of Education	2022	282	Holmes et al, 2022
2	Should AI-Based, conversational digital assistants employ social- or task-oriented interaction style? A task-competency and reciprocity perspective for older adults	Computers in Human Behavior	2019	282	Chattaraman et al, 2019
3	Unlocking the Power of ChatGPT: A Framework for Applying Generative AI in Education	ECNU Review of Education	2023	264	Su et al, 2023
4	Transforming Education: A Comprehensive Review of Generative Artificial Intelligence in Educational Settings through Bibliometric and Content Analysis	Sustainability	2023	257	Bahroun et al, 2023
5	Stupid Tutoring Systems, Intelligent Humans	International Journal of Artificial Intelligence in Education	2016	253	Baker et al, 2016
6	Artificial Intelligence (AI) Student Assistants in the Classroom: Designing Chatbots to Support Student Success	Information Systems Frontiers	2022	233	Chen et al, 2022
7	Synthesizing Results from Empirical Research on Computer-Based Scaffolding in STEM Education	Review of Educational Research	2016	225	Belland et al, 2016
8	Designing educational technologies in the age of AI: A learning sciences driven approach	British Journal of Educational Technology	2019	217	Luckin, 2018
9	Teacher support and student motivation to learn with Artificial Intelligence (AI) based chatbot	Interactive Learning Environments	2023	199	Chiu et al, 2023
10	Generative AI in Education and Research: Opportunities, Concerns, and Solutions	Journal of Chemical Education	2023	185	Alasadi et al, 2023

Authors with Publications and Citations

The analysis of the most influential authors in the field of AI in education, as presented in Table 3, identifies key contributors and their impact on the academic community. Gwo-Jen Hwang emerges as the most prolific author, with 11 publications and a total of 225 citations, yielding an average of 20.45 citations per article. This consistent citation rate reflects a sustained and significant contribution to the field. Dragan Gašević follows with five publications; however, his work exhibits a higher citation impact, averaging 43.20 citations per article, with a total of

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216 citations. This suggests that Gašević's research is widely recognized and highly influential within the academic discourse on AI in education.

Notably, Mutlu Cukurova demonstrates the highest average citations per publication at 101.25, with four articles accumulating a total of 405 citations. This exceptional citation rate indicates that Cukurova's research is not only impactful but also extensively referenced by peers, underscoring its scholarly significance. Other notable contributors include Kyungbin Kwon and Marcia C. Linn, with average citations per article of 22.33 and 15.67, respectively. Although they have produced fewer publications, their work has made substantial contributions to their respective areas within AI in education. In contrast, authors such as Jiyou Jia and Mingzhang Zuo exhibit lower average citations per article, suggesting that while their research is acknowledged, it does not yet reach the same level of influence as the top-ranked scholars.

The citation analysis highlights a diverse group of influential authors, each contributing uniquely to the advancement of AI in education. The variations in average citations per article underscore differing levels of impact and scholarly recognition, reflecting both the breadth and depth of research in this evolving field.

Table 3. Most influential authors

Rank	Author	Publications	Citations	Average Citations per Article
1	Hwang, Gwo-Jen	11	225	20.45
2	Gašević, Dragan	5	216	43.20
3	Luo, Heng	5	46	9.20
4	Cukurova, Mutlu	4	405	101.25
5	Jia, Jiyou	3	7	2.33
6	Kwon, Kyungbin	3	67	22.33
7	Linn, Marcia C.	3	47	15.67
8	Zuo, Mingzhang	3	12	4.00
9	Abu Khurma, Othman	2	11	5.50
10	Al-Zahrani, Abdulrahman M.	2	18	9.00

Organizations and Publications

Table 4. Top ten organisation for publication

Rank	Organization	Publications	Citations	Average Citations per Article
1	Central China Normal University	20	103	5.15
2	National Taiwan University of Science and Technology	12	272	22.67
3	University College London	9	503	55.89
4	Beijing Normal University	8	140	17.50
5	Monash University	8	465	58.13
6	Carnegie Mellon University	6	85	14.17
7	University Of Hong Kong	6	308	51.33
8	Wenzhou University	6	56	9.33
9	Zhejiang University	6	119	19.83
10	Arizona State University	5	23	4.60

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Table 4 highlights the top ten organizations contributing to scholarly publications, ranked by publication count. While Central China Normal University leads with 20 publications, its citation impact remains relatively modest at an average of 5.15 citations per article. In contrast, institutions with fewer publications, such as Monash University (8 papers, 58.13 citations per article) and University College London (9 papers, 55.89 citations per article), demonstrate significantly higher citation influence. This indicates that while research productivity is important, impact is better reflected in citation metrics.

Among the high-impact institutions, Monash University stands out with the highest average citations per article (58.13), followed closely by the University of Hong Kong (51.33) and University College London (55.89). These figures suggest that despite publishing fewer articles, these institutions produce research that is widely recognized and frequently referenced. National Taiwan University of Science and Technology also demonstrates a strong citation presence, with an average of 22.67 citations per article from 12 publications. Meanwhile, Arizona State University, despite being included in the ranking, has the lowest citation impact (4.60), suggesting its research may not yet be widely cited.

The presence of four Chinese institutions—Central China Normal University, Beijing Normal University, Wenzhou University, and Zhejiang University—reflects China's increasing research output. However, Australian and UK institutions, such as Monash University and University College London, exhibit a stronger citation impact per paper, indicating higher research influence. This pattern suggests that citation impact may be driven more by research quality and visibility than sheer publication volume.

The data reveals that institutions with fewer but highly cited publications likely benefit from strong research networks, high-quality studies, or access to influential publication platforms. Future bibliometric analyses could explore co-authorship patterns, interdisciplinary collaborations, and funding sources to provide a deeper understanding of these citation trends.

Countries and Publications

Table 5 depicts that the United States emerges as the leading contributor, with 103 publications, underscoring its dominant role in research productivity and innovation. China follows closely with 95 publications, highlighting its growing influence and active participation in the global research landscape. The United Kingdom, Taiwan, and Australia also make notable contributions, with 32, 29, and 24 publications, respectively, demonstrating their strong research capacities in this domain.

European nations, including Spain, Germany, and Finland, along with Asian countries such as Indonesia, Saudi Arabia, and Malaysia, exhibit moderate research outputs ranging from 21 to 17 publications. This balanced distribution suggests sustained scholarly engagement from both continents. Additionally, Canada and India, with 16 and 15 publications, respectively, further emphasize the widespread international participation in AI in education research. Countries with emerging research profiles, such as South Africa, Greece, and Jordan, contribute between 9 and 7 publications, signaling a growing interest in the field. Furthermore, nations such as

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Italy, Mexico, Pakistan, and Singapore, each with six publications, illustrate their involvement in the global research community, albeit at a smaller scale.

The data highlight the extensive and diverse nature of research contributions across different regions, with both established and emerging players actively shaping the discourse on AI in education. The findings underscore the increasing globalization of AI research, reflecting collaborative efforts to advance educational technology and innovation.

Table 5. Countries with scientific publication

Country	Publications	Country	Publications
United States	103	South Africa	9
China	95	Greece	8
United Kingdom	32	Netherlands	8
Taiwan	29	Jordan	7
Australia	24	Norway	7
Spain	21	South Korea	7
Indonesia	19	Italy	6
Saudi Arabia	19	Mexico	6
Germany	17	Pakistan	6
Malaysia	17	Singapore	6
Canada	16	Switzerland	6
India	15	Thailand	6
Finland	11	Brazil	5
Sweden	10	Denmark	5
Turkey	10	Ukraine	5
United Arab Emirates	10		

Top Ten Journal as per Publication

The analysis presented in Table 6 provides a comprehensive overview of the most prolific journals in the field of AI in education, examining both publication volume and citation impact. *Education and Information Technologies* ranks as the leading journal, with 31 publications and a total of 540 citations, resulting in an average of 17.42 citations per article. While this indicates a strong presence in the field, the average citation rate per article remains moderate compared to other journals. *Computers and Education: Artificial Intelligence* follows, with 19 publications and 343 citations, yielding an average of 18.05 citations per article. This slightly higher citation rate suggests that research published in this journal is well-regarded within the academic community.

Journals such as *Interactive Learning Environments* and *Computers & Education* demonstrate particularly high citation impact, with averages of 26.18 and 33.93 citations per article, respectively, despite publishing fewer articles (17 and 14). This highlights the significant scholarly influence and quality of research disseminated through these venues. Similarly, *Sustainability* exhibits a high average citation rate of 32.75 across 12 publications, indicating its substantial impact at the intersection of education and sustainability research.

Notably, the *International Journal of Artificial Intelligence in Education* and the *European Journal of Education* report the highest average citations per article, at 41.00 and 51.89,

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respectively, despite publishing a relatively lower number of articles (10 and 9). This suggests that research published in these journals is highly influential and widely cited. Conversely, journals such as *Education Sciences* and *Cogent Education* report lower average citations per article, at 7.38 and 5.50, respectively, indicating a comparatively lower impact per publication despite maintaining a steady output.

Overall, the findings highlight varying levels of influence and reach among the top journals in the field. While some journals achieve substantial impact through a select number of highly cited publications, others maintain consistent output with moderate citation rates, reflecting diverse publication and citation dynamics within AI in education research.

Table 6. Most articles publishing journals

Rank	Journal	Publications	Citations	Average Citations per Article
1	Education and Information Technologies	31	540	17.42
2	Computers and Education Artificial Intelligence	19	343	18.05
3	Interactive Learning Environments	17	445	26.18
4	Education Sciences	16	118	7.38
5	Computers & Education	14	475	33.93
6	Sustainability	12	393	32.75
7	Cogent Education	10	55	5.50
8	International Journal of Artificial Intelligence in Education	10	410	41.00
9	European Journal of Education	9	467	51.89
10	British Journal of Educational Technology	8	323	40.38

Co-authorship Analysis

The co-authorship analysis from this study uncovers intricate collaboration patterns and scholarly networks within AI and education research between 2016 and February 2025. Using VOSviewer for visualization, the analysis reveals dense networks of countries and organizations converging around key themes and questions Van Eck and Waltman (2010). in AI studies, showcasing a dynamic collaborative community. Mapping these connections provides insights into the central figures driving research through joint efforts, as well as the geographical and institutional landscapes of collaboration.

Co-authorship- Countries

Table 7 shows that the United States emerges as the leading contributor, with 103 publications, 2,773 citations, and a total link strength of 39. This prominence underscores the country's substantial research output and its strong influence within the academic community.

China follows closely with 95 publications and 1,287 citations. Notably, China surpasses the United States in total link strength, suggesting a more extensive network of research collaborations. This indicates that while the U.S. leads in overall citations, China's research community exhibits a high degree of interconnectedness and collaborative activity.

The United Kingdom ranks third, with 32 publications and 1,133 citations, highlighting the significant impact of its research despite a comparatively lower publication count. Australia

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and Taiwan also contribute meaningfully to the field, with 24 and 29 publications, respectively, alongside citation counts that reflect their research quality and influence.

Other notable contributors include India, Germany, Saudi Arabia, the United Arab Emirates, and Finland, each producing between 10 and 19 publications. Although their citation counts are relatively lower, their presence among the top research-producing nations underscores their growing engagement in AI in education research and their increasing participation in international collaborations.

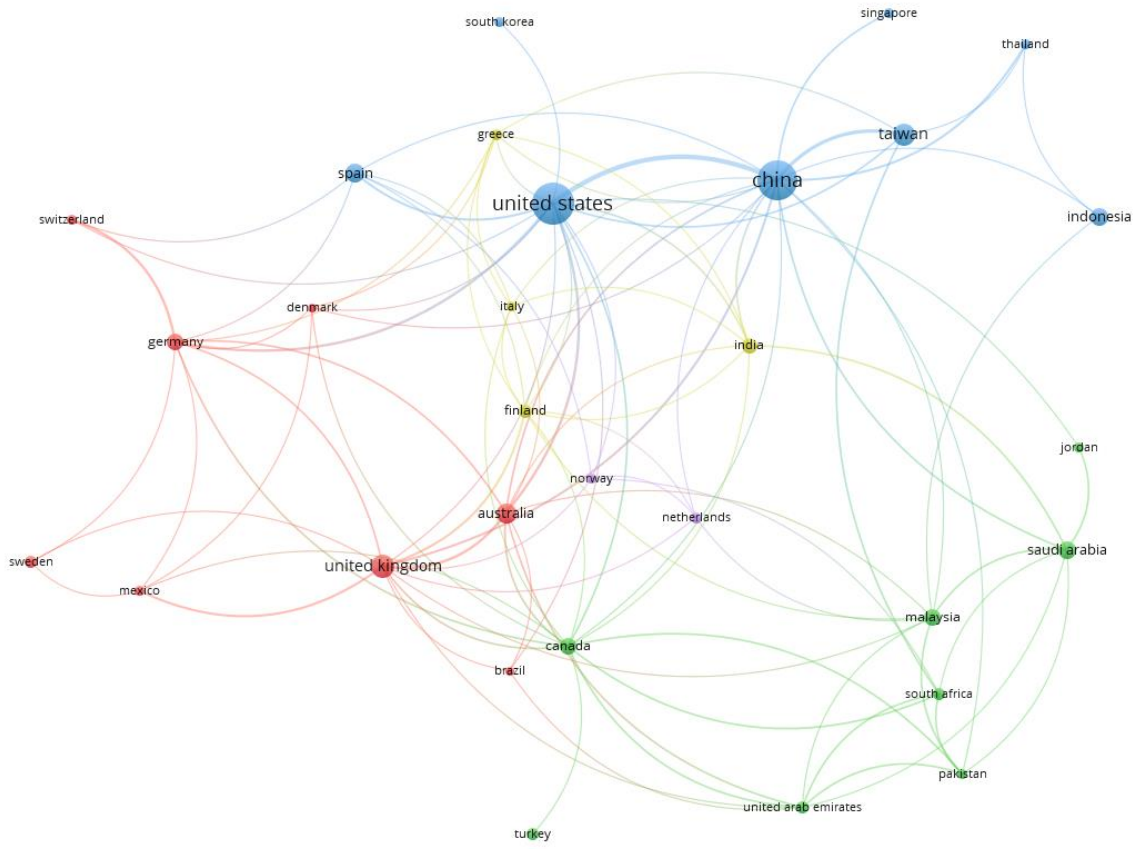
The data illustrate a diverse and interconnected global research landscape, characterized by varying levels of publication output, citation impact, and collaborative linkages. The findings highlight the dynamic nature of AI in education research, with both established and emerging research hubs contributing to its advancement.

Table 7. Leading countries contributing publication

Rank	Country	Publications	Citations	Total Link Strength
1	United States	103	2773	39
2	China	95	1287	44
3	United Kingdom	32	1133	24
4	Australia	24	594	20
5	Taiwan	29	431	13
6	India	15	427	11
7	Germany	17	410	19
8	Saudi Arabia	19	377	11
9	United Arab Emirates	10	345	12
10	Finland	11	339	12

Nepal Journal of Multidisciplinary Research (NJMR)
Vol. 8, No. 2, Special 1, 2025. Pages: 161-185
ISSN: 2645-8470 (Print), ISSN: 2705-4691 (Online)
DOI: https://doi.org/10.3126/njmr.v8i2.78026

Figure 2. Co-authorship – countries network



Co-authorship - Organizations

University College London (UCL), as shown in Table 8, ranks first, with nine publications and 503 citations, indicating a high research impact despite a relatively lower total link strength of 1. Monash University follows closely, with eight publications and 465 citations. Notably, it has a higher total link strength of 4, suggesting a more extensive network of research collaborations.

The University of Hong Kong and the Education University of Hong Kong demonstrate significant research influence, with six and five publications, respectively, and citation counts of 308 and 288. These figures highlight the quality and academic reach of their research contributions. National Taiwan University of Science and Technology emerges as the most prolific institution in terms of publication output, with 12 publications. However, its moderate citation count of 272 suggests that while its research is extensive, its overall impact remains steady rather than exceptionally high.

Other institutions, including the University of South Australia, Beijing Normal University, and Zhejiang University, exhibit moderate publication counts (five, eight, and six, respectively) and varying citation impacts. The University of South Australia stands out with a total link strength of 4, indicating strong research collaborations. Central China Normal University, despite

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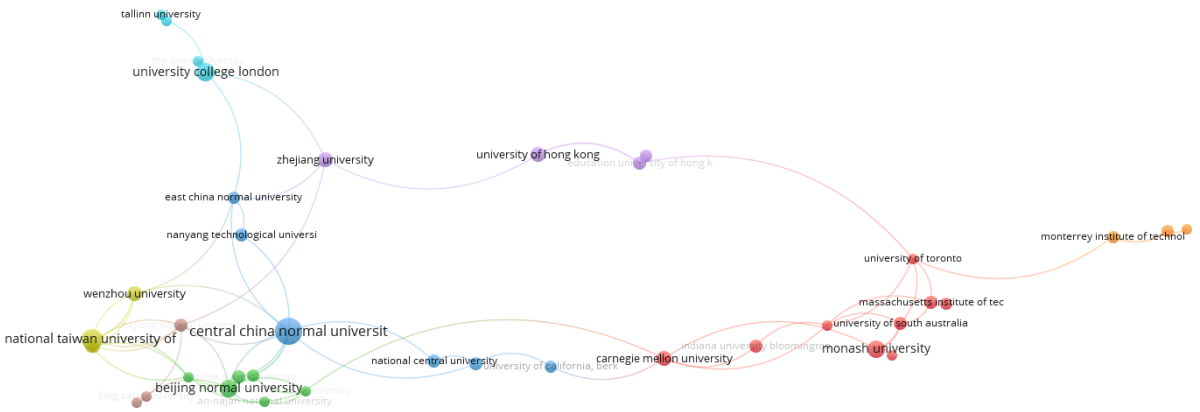
having the highest publication output among the listed institutions (20 publications), records a comparatively lower citation count of 103. This discrepancy suggests that while its research volume is substantial, its influence within the broader academic community may require further enhancement.

Indiana University Bloomington completes the list, with five publications and 99 citations, maintaining a total link strength of 1. The analysis highlights the diverse research productivity and impact among leading institutions in AI in education. The findings underscore variations in publication output, citation influence, and collaborative networks, emphasizing the different strengths and research strategies adopted by these institutions.

Table 8. Top ten organizations as per research productivity

Rank	Organization	Publications	Citations	Total Link Strength
1	University College London	9	503	1
2	Monash University	8	465	4
3	University of Hong Kong	6	308	3
4	Education University of Hong Kong	5	288	2
5	National Taiwan University of Science and Technology	12	272	3
6	University of South Australia	5	210	4
7	Beijing Normal University	8	140	2
8	Zhejiang University	6	119	3
9	Central China Normal University	20	103	5
10	Indiana University Bloomington	5	99	1

Figure 3: Co-authorship – Organizations network



Bibliographic Coupling

Bibliographic coupling is a bibliometric method used to measure the frequency with which two documents share references. This technique helps to identify the relationships and similarities between different research papers based on their shared references. When two documents have a high number of shared references, it suggests a strong semantic connection between them, indicating that they may cover related topics or contribute to a similar field of study (Kessler, 1963; Boyack & Klavans, 2010). Bibliographic coupling is particularly useful for mapping the

Nepal Journal of Multidisciplinary Research (NJMR)
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intellectual structure of a research area and identifying influential works within that domain (Boyack & Klavans, 2010).

Bibliographic coupling - Countries

Table 9 shows that the United States emerges as a dominant force, leading with the highest number of documents (103) and citations (2773), reflecting its prominent role in research productivity and global influence. Its substantial total link strength of 13,986 further underscores its extensive collaboration and connectivity within the international research community.

China ranks second, with 95 documents and 1287 citations, demonstrating its significant contribution to the global research landscape. Its total link strength of 13,229 highlights China's robust network of research collaborations. The United Kingdom, with 32 documents and 1133 citations, also maintains a strong research presence, underpinned by a total link strength of 6799.

Australia, Taiwan, and India exhibit moderate research output, with 24, 29, and 15 documents, respectively. However, their citation counts (594, 431, and 427) and total link strengths (4813, 3417, and 4274) indicate their growing influence and increasing engagement in collaborative research endeavors.

Germany, Saudi Arabia, and the United Arab Emirates, although contributing fewer documents (17, 19, and 10), exhibit significant citation counts (410, 377, and 345) and total link strengths (4040, 4634, and 4326), demonstrating their impactful contributions and strong international research partnerships. Finland, with 11 documents, 339 citations, and a total link strength of 3418, completes the top ten, signifying its active participation in the global research sphere. The analysis highlights the diverse and collaborative nature of global research, illustrating that each country plays a unique and integral role in the advancement of knowledge.

Table 9. Research impact of countries

Rank	Country	Documents	Citations	Total Link Strength
1	United States	103	2773	13986
2	China	95	1287	13229
3	United Kingdom	32	1133	6799
4	Australia	24	594	4813
5	Taiwan	29	431	3417
6	India	15	427	4274
7	Germany	17	410	4040
8	Saudi Arabia	19	377	4634
9	United Arab Emirates	10	345	4326
10	Finland	11	339	3418

Nepal Journal of Multidisciplinary Research (NJMR)
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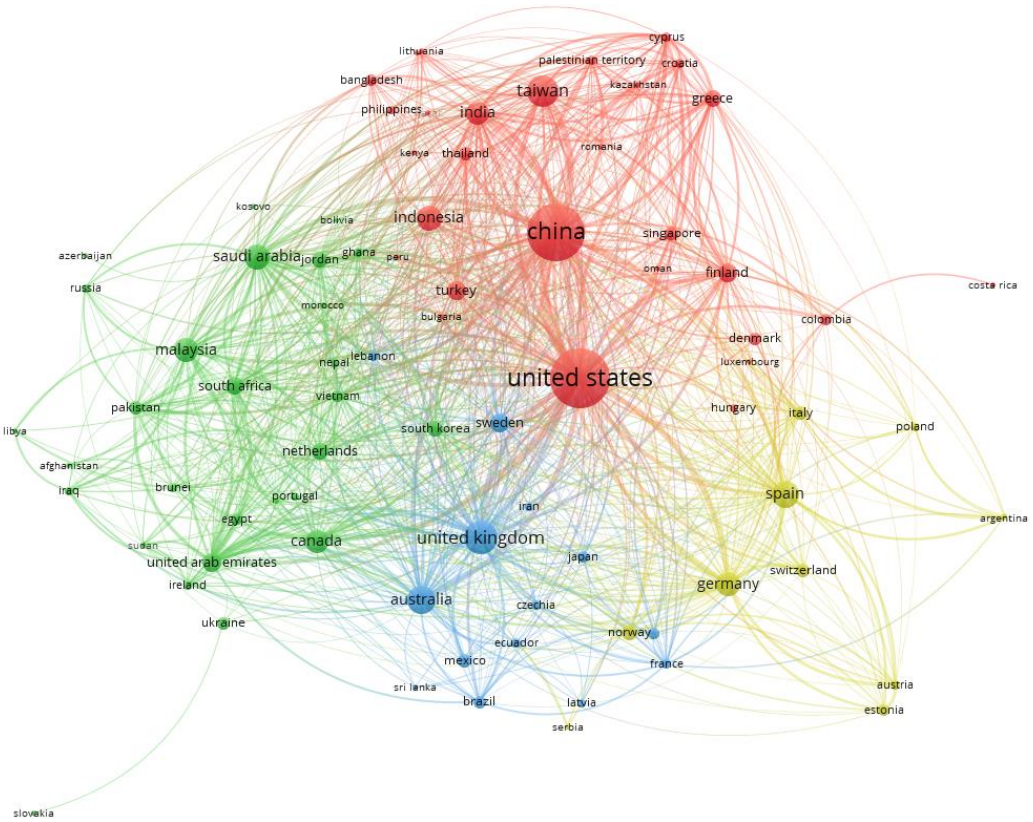
Figure 4: Bibliographic coupling – Countries network



Bibliographic Coupling – Organizations

The analysis of research output from various institutions reveals distinct patterns of productivity, impact, and collaboration in Table 10. University College London (UCL) emerges as the leading institution, with the highest number of documents (9), citations (503), and total link strength (3291). These figures highlight UCL's substantial influence and extensive connectivity within the global research community.

Monash University follows closely, contributing 8 documents and 465 citations, reflecting a strong research presence and notable impact. Its total link strength of 1767 further emphasizes its role in fostering collaborative research networks. The University of Texas at Austin and Auburn University each produced 4 documents, although the former has a lower citation count (350) in comparison to Auburn's 307. However, Auburn's total link strength (2314) is significantly higher, indicating a more robust and interconnected research network.

The University of Hong Kong and Education University of Hong Kong also demonstrate notable research activity, with 6 and 5 documents, respectively. The University of Hong Kong surpasses Education University of Hong Kong in both citation count (308) and total link strength (2049), signifying its broader research impact and stronger international collaboration.

National Taiwan University of Science and Technology, with the highest number of documents (12) among the listed institutions, exhibits a relatively lower citation count (272) and total link

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strength (2296). This suggests a high volume of research output but with moderate impact and connectivity within the research community.

Smaller institutions such as Meaning Processing (Finland) and the American University of Sharjah, despite having fewer documents (2 and 1 respectively), demonstrate high citation counts (286 and 257) and significant total link strengths (714 and 1469). This indicates that their research, though lower in volume, has a strong impact and is highly connected within the research network. In conclusion, the analysis underscores the varying levels of research productivity, impact, and collaboration across these institutions, with UCL standing out as the most influential entity within this group.

Table 10. Research output of institutions

Rank	Organization	Documents	Citations	Total Link Strength
1	University College London	9	503	3291
2	Monash University	8	465	1767
3	The University of Texas at Austin	4	350	350
4	University of Hong Kong	6	308	2049
5	Auburn University	4	307	2314
6	University of Florida	3	291	434
7	Education University of Hong Kong	5	288	1052
8	Meaning Processing (Finland)	2	286	714
9	National Taiwan University of Science and Technology	12	272	2296
10	American University of Sharjah	1	257	1469

Co-citation Analysis

Co-citation analysis is a bibliometric method used to measure the frequency with which two documents are cited together by other documents. This technique helps to identify the relationships and similarities between different research papers based on their citation patterns. When two documents are frequently co-cited, it suggests a strong semantic connection between them, indicating that they may cover related topics or contribute to a similar field of study (Kessler, 1963; White & McCain, 1998). Co-citation analysis is particularly useful for mapping the intellectual structure of a research area and identifying influential works within that domain (White & McCain, 1998).

Co-citation - Cited authors

Table 11 reveals that Richard E. Mayer ranks first, with seven citations and a total link strength of five, indicating his substantial influence and significant connectivity within the research community. Edward L. Deci and Richard M. Ryan closely follow, each with six citations and a total link strength of six, reflecting their prominent contributions to the field and robust collaborative networks.

The remaining authors—Jacqueline Chandler, Miranda Cumpston, Julian P.T. Higgins, Tianjing Li, Matthew J. Page, James Thomas, and Vivian A. Welch—each have three citations and a total link strength of three. This uniformity in their citation and link strength values

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suggests a comparable level of impact and interconnectedness within the research domain. The analysis highlights the varying degrees of scholarly influence and collaborative engagement among the most cited authors in the field.

Table 11. Top ten authors with citation counts

Rank	Author	Citations	Total Link Strength
1	Mayer, Richard E.	7	5
2	Deci, Edward L.	6	6
3	Ryan, Richard M	6	6
4	Chandler, Jacqueline	3	3
5	Cumpston, Miranda	3	3
6	Higgins, Julian P.T.	3	3
7	Li, Tianjing	3	3
8	Page, Matthew J.	3	3
9	Thomas, James	3	3
10	Welch, Vivian A.	3	3

Co-citation – Cited sources

Table 12 offers valuable insights into the landscape of educational technology research. *Computers & Education* stands out as the most influential source, with an impressive 1114 citations and a total link strength of 945.07, underscoring its central role in the field. The journal's high citation count and link strength reflect its significant contributions and widespread recognition within the academic community.

Education and Information Technologies and *Interactive Learning Environments* occupy the second and third positions, with 534 and 452 citations, respectively. Their total link strengths of 492.06 and 407.64 further highlight their substantial impact and strong interconnectedness in the research domain. These journals play a pivotal role in disseminating innovative educational technologies and interactive learning methodologies.

Computers in Human Behavior and the *British Journal of Educational Technology* are also prominent sources, each surpassing 400 citations, with total link strengths of 393.57 and 372, respectively. These publications are critical in exploring the intersection of technology and human behavior, as well as advancing the field of educational technology.

The emergence of *Computers and Education Artificial Intelligence*, with 398 citations and a link strength of 361.78, indicates the growing interest in the application of artificial intelligence in education. Similarly, *Lecture Notes in Computer Science* and *Sustainability* maintain their relevance in the field, with citations in the 300s and notable link strengths, signifying their contributions to computer science education and the integration of sustainable educational practices.

Finally, the *International Journal of Educational Technology in Higher Education* and *Educational Technology Research and Development* complete the top ten, with 318 and 264 citations, respectively. Their total link strengths of 302.48 and 255.71 highlight their importance in the development and application of educational technologies in higher education.

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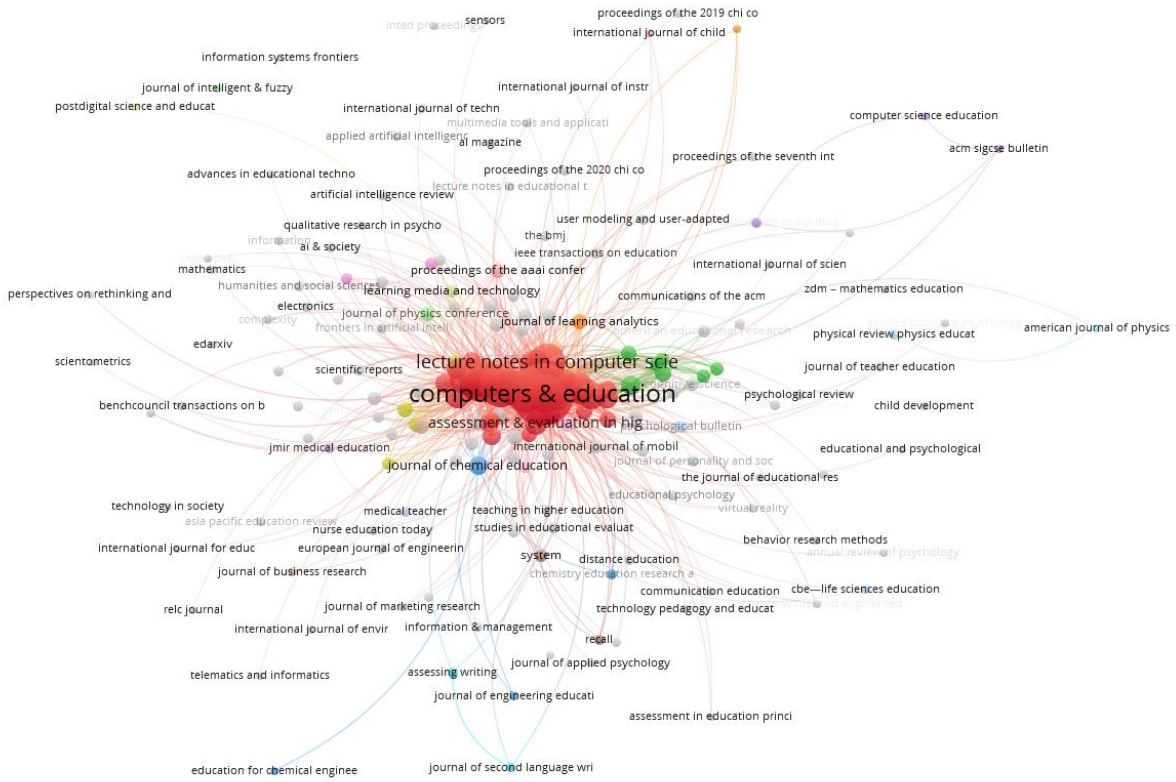
The analysis underscores the diverse range of influential sources shaping the field of educational technology, with particular emphasis on the integration of technology in education, the promotion of interactive learning environments, and the growing application of artificial intelligence and sustainability principles.

Table 12. Top ten influencing journals

Rank	Journals	Citations	Total Link Strength
1	Computers & Education	1114	945.07
2	Education and Information Technologies	534	492.06
3	Interactive Learning Environments	452	407.64
4	Computers in Human Behavior	418	393.57
5	British Journal of Educational Technology	401	372
6	Computers and Education Artificial Intelligence	398	361.78
7	Lecture Notes in Computer Science	387	327.6
8	Sustainability	332	300.43
9	International Journal of Educational Technology in Higher Education	318	302.48
10	Educational Technology Research and Development	264	255.71

Figure 5: Co-citation – Cited sources network



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Analysis of Key Research Themes

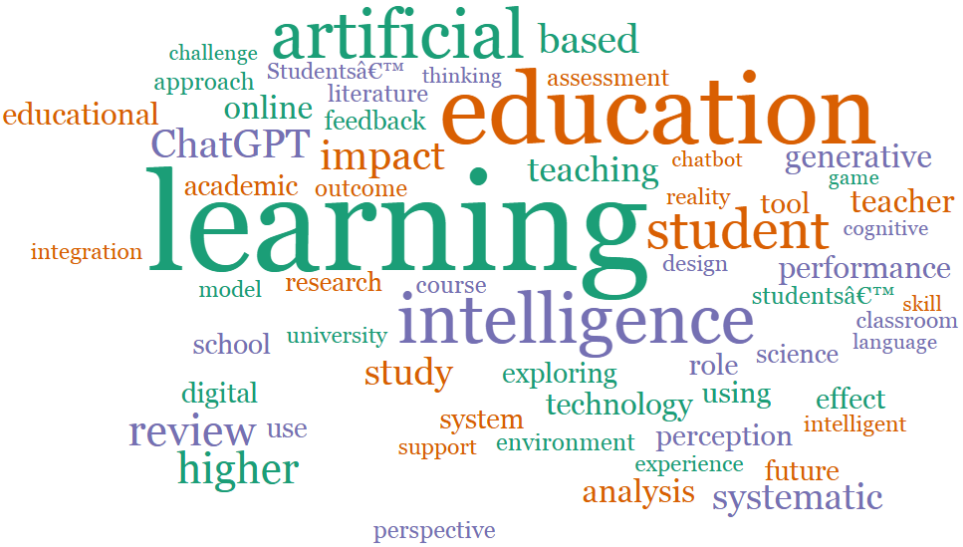
Figure 6 depicts the word cloud visualization provides an insightful overview of dominant themes in contemporary research, derived from publication titles. The most frequently occurring terms—"learning," "education," "intelligence," "artificial," and "student"—indicate a strong research focus on the integration of artificial intelligence (AI) in education and student learning. The prominence of "ChatGPT" further underscores the increasing interest in AI-driven language models and their applications in educational contexts.

A closer look at the word cloud reveals key sub-themes. Terms like "assessment," "performance," "feedback," and "perception" suggest that researchers are investigating AI's role in evaluating student learning and enhancing academic performance. The presence of words such as "systematic," "review," "analysis," and "exploring" indicates a growing body of literature analyzing the broader implications and effectiveness of AI-based educational technologies. Additionally, the frequent appearance of "higher," "university," and "digital" suggests that AI adoption in higher education is a particularly active area of study.

The visualization also highlights the ethical and pedagogical considerations surrounding AI in education. Terms like "role," "technology," "support," "experience," and "integration" suggest an ongoing discussion about the challenges and opportunities AI presents for teachers and students. Moreover, the inclusion of "future," "challenge," and "impact" points to a forward-looking perspective, where scholars are considering the long-term effects of AI-driven learning environments.

The analysis of this word cloud confirms that research is heavily centered on AI's transformative potential in education. Future studies are likely to delve deeper into ethical considerations, adaptive learning models, and the balance between human and AI involvement in education. This visualization serves as a valuable tool for understanding the current research landscape and emerging trends in the field.

Figure 6. Word cloud from the research topics



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Discussion

The findings of this study are consistent with several prior studies in the field of AI in education. The significant increase in AI-related educational research from 2021 onwards aligns with the observations made by Mustafa et al. (2024), who noted a growing body of literature on AI in education, particularly in higher education and teacher support (Mustafa et al., 2024). This trend underscores the expanding interest and advancements in AI-driven learning systems and adaptive technologies.

The global disparities in AI adoption, highlighted in this study, are also consistent with the findings of Chatterjee and Bhattacharjee (2020). They emphasized the digital divide and the need for strategies to bridge technological gaps, particularly in developing nations. This study's identification of infrastructure and resource constraints in developing countries further supports this observation.

Ethical considerations and data privacy concerns, as discussed in this study, resonate with the work of Luckin and Holmes (2016). They highlighted the challenges of designing fair and reliable AI systems in education, emphasizing the importance of addressing algorithmic biases and ensuring equitable access to AI technologies.

The transformative potential of AI in education, as highlighted in this study, is supported by Bojorquez and Vega (2023). They discussed how AI can advance learning practices, support teachers, and create personalized learning opportunities. This study's findings on the impact of AI on teaching and learning align with these observations.

While the current study's findings are largely consistent with prior research, there are some areas of inconsistency. For instance, the sharp decline in citation counts in 2018 and 2025, as observed in this study, contrasts with the generally upward trend reported by Ouyang et al. (2023). They noted a steady increase in citations over the years, reflecting continuous research interest and activity in AI in education. The fluctuations in citation trends observed in this study suggest periods of heightened research activity interspersed with years of lower citation counts, which may indicate varying levels of research output and interest over time.

Additionally, the current study's identification of the most influential authors and their citation counts reveals some differences from previous studies. While Gwo-Jen Hwang and Dragan Gašević are recognized as key contributors in both this study and prior research, the exceptionally high average citations per article for Mutlu Cukurova (101.25) in this study is notably higher than averages reported in earlier studies. This discrepancy may be due to differences in the timeframes and datasets analyzed.

Conclusion

In conclusion, the integration of AI-driven technologies into education is transforming traditional learning environments into more personalized, adaptive, and data-driven experiences. This shift is redefining the roles of educators and students, fostering interactive and customized approaches to knowledge dissemination. The study's bibliometric analysis highlights the significant growth in AI-related educational research, particularly from 2021

onwards, indicating a surge in interest and advancements in AI-driven learning systems and adaptive technologies.

However, the global disparities in AI adoption present a critical challenge. While developed countries have rapidly integrated AI into their educational systems, developing nations face infrastructure and resource constraints, exacerbating the digital divide. Addressing these disparities requires strategic efforts to bridge technological gaps and promote inclusive AI adoption worldwide.

The findings underscore the importance of addressing ethical considerations, data privacy, and algorithmic biases to ensure equitable access to AI technologies. The analysis also reveals key research trends, influential contributors, and the evolving landscape of AI in education, providing valuable insights for future research directions.

Overall, the study emphasizes the transformative potential of AI in education while highlighting the need for inclusive and ethical implementation to maximize its benefits across diverse educational contexts.

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Nepal Journal of Multidisciplinary Research (NJMR)
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